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APPLICATIONS OF COMPUTERIZED DIGITAL DATA ACQUISITION SYSTEMS

Minicomputer system benefits fuel cell technology

A Solution to a Measurement Problem for: PRATT & WHITNEY AIRCRAFT DIV.
United Aircraft Corp.
East Hartford, Conn.

Minicomputer system benefits fuel cell technology

A Hewlett-Packard computerized digital data acquisition system is being used in a technology field that is so new most people have heard little about it – fuel cells.

Fuel cells produce electricity quietly, cleanly, efficiently and without combustion, through an electrochemical process combining fuel and oxygen. Known as a principle for more than a century, the technology finally came into its own through the space program. Three fuel cell powerplants, each capable of producing over 2 kilowatts of electricity, provide all the power needs for the Apollo spacecraft that carry astronauts on their missions out to the moon and back. They have operated successfully in space for more than 5,000 hours.

Spurred on by the success of the Apollo fuel cells, their manufacturer, Pratt & Whitney Aircraft, now conducts a broad range of research and development programs at its South Windsor, Connecticut plant to explore earthbound uses for these remarkable powerplants. These include programs for the utility industry, for undersea power supplies, and for special purpose applications.

The company emphasizes that earthbound uses of fuel cells are still in the experimental stage; nevertheless, its efforts, which began back in 1958, to see if fuel cell powerplants could be offered on the commercial market, are being carried on, supported by large investments from potential customers.

THE NEED FOR COMPUTERIZED TESTING

P & WA's technical leadership in fuel cell development and production is complemented by the considerable effort it devotes to product quality control and reliability, with emphasis on a very comprehensive testing program. The newness of the product and the stringent operating requirements of users such as NASA, necessitate that many tests be performed and a sufficient amount of test data be acquired to verify compliance with specifications. Currently, P & WA is working on several different technologies within the overall fuel cell technology, and each of these requires vast amounts of test data. The sheer amount of test data needed, the fact that accurate test results are essential, the fact that several technologies are being worked on at the same time requiring multi-testing capability, and the fact that new fuel cell technologies are anticipated, clearly indicate that only a highly-flexible computerized data acquisition system could supply the measurement needs.

COVER:

Inset shows the Powercel 11, an experimental Pratt & Whitney Aircraft 12½ Kw natural gas fuel cell powerplant. Unit at left houses the reformer, to process the fuel, and the fuel cell power section; unit at right houses the inverter, which converts DC electricity to AC. Powercel 11s are being field tested in a variety of commercial buildings, apartments, and single family homes around the country.

CONFIGURING THE TEST SYSTEM

The P & WA test application is an excellent example of starting out with a computerized data acquisition system to supply immediate testing needs and, at the same time incorporating features which allow future expansion, as needed, at minimum cost and with minimum system downtime. Initially, the test equipment requirements were based on testing spacecraft Powercels® in accordance with NASA specifications. These needs were quite adequately met by an HP 2116 computer system. Over 200 inputs (temperature, pressure, and voltage) were measured and converted to engineering units, as required, for output on a teleprinter, either in typewritten form and/or punched paper tape. After a few months of successful operation, a more advanced Powercel was ready for testing, followed by others shortly thereafter. This led to extensive upgrading of the original computerized system to meet the increased testing needs, and also to allow for additional capability that would very likely be needed in the future. The system was expanded to include additional computer memory for more capability in both acquisition and manipulation of data, plus a greatly enlarged input capacity for *testing several fuel cell technologies simultaneously*. Further, the system now automatically controls fuel cell load profiles and emergency shutdown of test stands. The present computerized test system is shown in the block diagram, Figure 1.

The ambient temperature in the test lab occasionally climbs above 100°F in the summertime. Because of this, and to avoid possible dust contamination, P & WA installed the computer, certain peripherals, and elements of the measurement subsystem (digital voltmeter and scanner control) in the control room, shown in Figure 2, while the remaining elements were installed in the lab close to the test stands, Figure 3. While the distance between the test stands and control room is approximately 300 feet, there is no noticeable degradation from noise in the system – thanks, to a large extent, to the excellent noise rejection characteristics of the HP integrating digital voltmeter (A to D converter). Notice, also, that all input switching is done at the test stands, through the HP 2911A Scanner, thus saving the costs otherwise required to bring separate signal lines from each test point to the digital voltmeter.

At the heart of the system is an HP 2116 Computer with 24K 16-bit words of memory. A heavy-duty teleprinter in the control room is used for general purposes of communication with the system. The high-speed punched tape input (reader) is used to read source and binary programs, data, long edit files, etc. into the system. The high-speed punched tape output is used whenever a paper tape copy of an edited source program, binary program, etc. is desired. The disc memory is used for program storage. The scanner control includes the control circuits for the remote scanner switches at the test stands. The scanner expander allows a single scanner control unit to handle all of the remote scanner switching units in the test areas. The heavy-duty teleprinter at the test stand allows a test engineer to communicate with the system to request printouts, change parameters, etc.

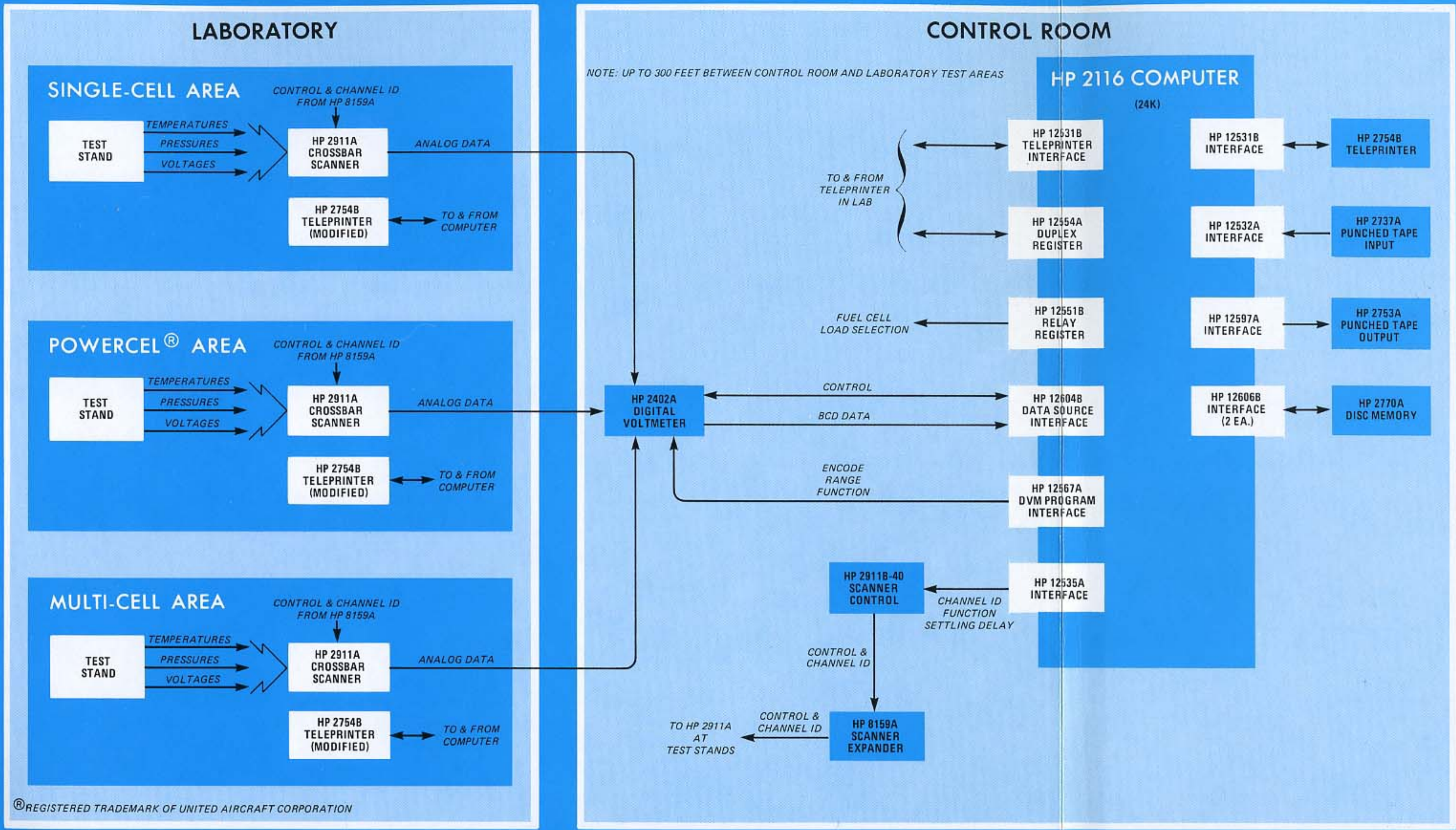

Figure 1. A typical configuration of P & WA's computerized system for testing fuel cells. The configuration may vary from that shown to accommodate more test areas and other types of fuel cells.

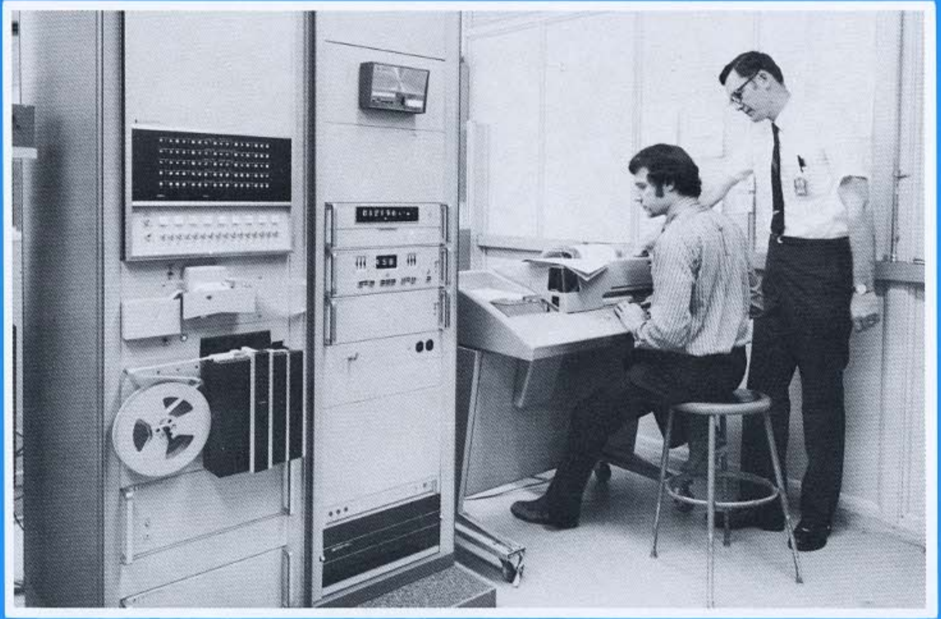

Figure 2. In the control room, programmers are using the foreground-background feature of the RTE to develop new test programs while the computer system (left) is on-line to the remote test stands.

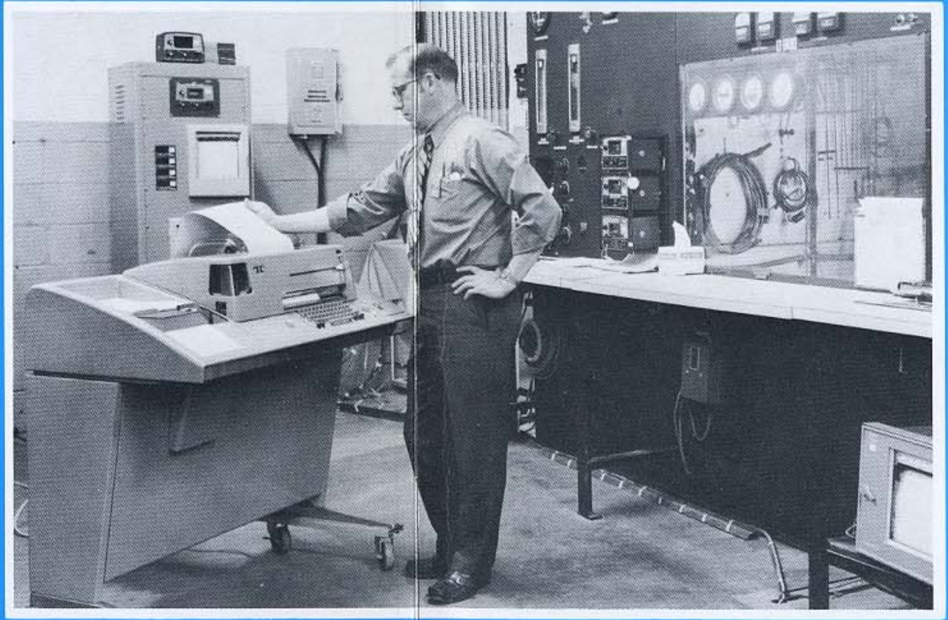

Figure 3. At a remote test stand, a test engineer is scanning a printout of some channels he selected to check for possible discrepancies. The fuel cell under test is located in back of the clear plastic window in the panel.

ON-LINE DYNAMIC FLEXIBILITY

The entire system is under control of the HP real-time executive (RTE) software operating system which allows P & WA to operate multiple test stations *on-line* and on a *simultaneous* basis. Particularly important to P & WA is that while real-time acquisition of data is in progress, lower priority activities, such as developing programs for future technologies, can take place. *This feature makes it possible, for example, to conduct a 10,000-hour fuel cell endurance test and do on-line program development at any time, with absolutely no interruptions to the test in progress.* Real-time data acquisition is handled in a section of computer memory designated as foreground, while low-priority activities are handled in the background area of core.

The RTE software operating system allows a dynamic and flexible approach to testing with its real-time, foreground-background, and multiprogramming capabilities. P & WA is very successfully utilizing the power of the RTE software to achieve high quality test results throughout its multiple-test facility. Some significant features contributing to this success include:

- On-line program modifications. In background mode, program changes can be made on-line without disturbing the data acquisition sequence. (Contrast this with other real-time systems which require that all measurement parameters be specified in the initial program; subsequent changes can then only be made by shutting down the system and in some cases, recompiling.) Some program changes routinely made on-line include: (a) changing channel assignments, (b) updating constants used for correcting data, and (c) specifying which channels are to be scanned. Complete new technologies can be added at any time without shutting down the system or even disturbing any tests in progress.
- On-line management information. Test supervisors can request a hard copy of the status of all tests in the RTE system. Thus, at any given time, a capsule summary of the entire test facility is available from the control room console, giving such management information as: (a) number of test stands currently on-line, (b) number of hours each stand has been operating, and (c) identification of each test stand.
- On-line error correction. The computer performs conversions on-line to compensate for transducer non-linearity and other error-causing factors. Thus, corrected data is available immediately, without waiting for subsequent off-line reduction.
- On-line profile control. The RTE system allows loads on cells under test to be changed by means of a relay register in the computer. The relays are programmed to change the load profiles on-line, as selected by the test engineers.
- Emergency shutdown control. In the event that certain critical parameters at a test stand exceed preset limits, the computer system automatically shuts down that stand. This vital feature allows around-the-clock testing without the need for a technician otherwise required to be present at all times to handle such occurrences.

SYSTEM OPERATION

While there are several different fuel cell technologies under development at P & WA, each involves certain common measurements, including: temperatures, pressures, cell voltages, and some general test stand parameters. On the other hand, certain differences exist, such as: test stand identification (header information), channel number assignments, transducer coefficients, and other special parameters peculiar to a specific technology. Typically, more than 150 different data points are measured at each test stand.

Using the multiprogramming, foreground-background capabilities of the RTE software system, P & WA has prepared a number of *general* programs, dynamic in nature, to handle its fuel cell testing needs. The significance of the system's disc storage capability becomes very important because these programs are stored on disc and called into core only when needed for execution. *Thus, the individual test programs for each technology are written as though they were the only programs in the entire system, and the test engineers operate each test stand accordingly.*

When the test engineer, at the test stand, wishes to get the attention of the system, he merely operates a request toggle switch on the teleprinter. The computer recognizes which test stand is making the request and causes the teleprinter to print out a question asking which "command" the engineer desires. The commands are actually computer programs (more are being added as needed) which are selected by typing a number, alongside the computer's command request, corresponding to the program required. Some of the computer programs available, as used in a recent fuel cell testing program, are as follows:

(1) A check of certain key parameters, at specified time intervals, for out-of-limits conditions. If necessary, the test stand will be automatically shut down to prevent damage to the hardware.

(2) A summary printout (about 40 seconds) in which all channels are scanned but only certain channel values are printed out on the teleprinter. This provides a quick look at certain parameters including voltage level at certain fuel cells, fuel cell (stack) voltage, load levels, and terminal voltage. A typical summary printout is shown in Figure 4.

(3) A three-minute printout of all the summary parameters plus some temperatures, additional voltages, and some calculated values. Printouts are in engineering units as required.

(4) A complete printout of every channel. This requires about four minutes.

(5) A program which allows the test engineer to select any channel, to a maximum of twenty. Each channel is scanned and its value printed out in engineering units.

BENEFITS OF COMPUTERIZED DATA ACQUISITION

The tremendous amount of printed measurement data acquired through extensive testing is serving P & WA and fuel cell users as an exceptionally valuable source of original information on fuel cell characteristics. For example, should a problem develop in a customer installation, the customer may use the test data to compare with that being measured in his system to determine the exact nature of the problem. P & WA utilizes the acquired data as the basis for verification of fuel cell operation in accordance with user specifications. The data also serves as an invaluable reference source for ongoing fuel cell development.

By taking advantage of capability already existing in the real-time computerized system, P & WA expects to place many of the manually-operated controls under closed-loop mode of operation in the near future. Thus, the test engineer will be free to concentrate his efforts toward more constructive aspects of testing.

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                 *** DM-1 TEST PROGRAM ***

ENGINE X-589-1   STAND X-755   TIME 1046   DATE  6/25/71   R HRS.   739

LOAD =     .0 AMPS   STACK VOLTAGE=  .00 V   AVG. CELL VOLTAGE= -.000V

*** CELL VOLTAGES ***

 HIGH CELLS-                                  LOW CELLS-
    2      3      4      5      6              29     30     31     32     9
  .000   .000   .000   .000   .000           .000   .000   .000   .000 -.000

*** COOLANT LOOP TEMPERATURES (DEG-F) ***

STACK INLET    .000     PUMP EXIT  .000     INTERFACE IN     .000
STACK EXIT     .000     COND EXIT  .000     INTERFACE OUT    .000

*** HYDROGEN SYSTEM TEMPERATURES (DEG-F) ***

STACK EXIT   .000   COND EXIT  .000   MAKE-UP MIX  .000   PUMP EXIT  .000

*** PRESSURES (PSI) ***

O2 STACK INLET -.2   H2 STACK INLET  .0   COOLANT STACK EXIT  .2

% CONCENTRATION IN =    .0            % CONCENTRATION OUT =    .0
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Figure 4. A summary printout of a typical fuel cell under test. The engineer requests this quick-look analysis (through the remote keyboard) mainly for initial start-up and checking critical points. He can also key-in a request for an intermediate printout listing summary readings plus a few other parameters. Similarly, he can request a complete printout of parameters, plus calculations, when desired for detailed analysis of total power plant performance and historical data recording. (Zeros are used to protect proprietary aspects of the fuel cell power system.)

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